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1890 observations, are 5007.0 and 4959. The line in the yellow is too faint for measurement. The lines are broad, as in the spectrum of *Nova Aurigæ*. More accurate measures than the above cannot be made here, and subsequent observations will be confined to noting any possible variations in brightness.

Both *Nova Aurigæ* and *Nova Normæ* at discovery possessed substantially identical spectra of bright and dark lines. Both diminished in brightness and both assumed the nebular type of spectrum. The new star of 1876 in the constellation *Cygnus* probably had an identical history: passing from a bright star with a spectrum of bright and dark lines, to a faint star with a spectrum in which only one bright line was seen (probably the bright nebular line at 5007). We cannot say just what the significance of two or three "new stars" with identical histories will be, but it will be great. Only five new stars have been discovered since the application of the spectroscope to astronomical investigation, and that three of these should have similar spectroscopic histories is a remarkable fact, and an encouraging fact to students of these most interesting objects.

AN EXPLANATION OF THE BRIGHT PROJECTIONS OBSERVED ON THE TERMINATOR OF *MARS*.

BY W. W. CAMPBELL.

An extremely favorable opposition of *Mars* is rapidly approaching. Useful observations can probably begin in June and continue into the year 1895. It is known that many astronomers are preparing to expend a great deal of energy upon that planet, and are expecting more valuable results than have been obtained at any previous opposition. We shall undoubtedly have interesting accounts of the progress of their work, both in the scientific journals and in the public press, which everyone, astronomers included, will welcome. It is, unfortunately, perfectly safe to predict that we shall also hear from the sensationalists, astronomers included; and that fact is a source of sincere regret to all healthy minds.

Nearly all the problems concerning *Mars* are still awaiting solution. It is difficult to mention any, indeed, except some of those relating to the polar caps, that have been solved

satisfactorily. There are a few points to which I wish to refer before the observing season begins, which, it seems to me, are of great significance.

SCHIAPARELLI has often called attention to the appearance of intensely bright spots upon the planet, and he has attributed to them very great importance in the study of its physical constitution. While this distinguished observer has not, so far as I know, seen these bright regions *projecting beyond the terminator*, he has made it plain* that they are relatively much brighter at the edge of the planet than near its center. That they are phenomena connected with the surface of the planet, in some way, follows from their more or less permanent character.

Three white spots were observed on eight or ten nights in 1888 by TERBY† which were invisible until they approached the western edge of the disc, when they became very bright, and before passing behind the planet projected beyond the edge of the disc by irradiation, as is the case with the polar cap. While it is not clear to me that all of M. TERBY'S observations refer to the same three points, it is probable that most of them do, and that the points were more or less permanent in their character. The terminator was on the western edge of the disc during the first few nights of the observations referred to, but for the greater number the terminator was on the eastern edge.

White spots, similar to those described by SCHIAPARELLI and TERBY, were frequently observed at Mount Hamilton in 1888, 1890 and 1892; but the brilliant projections on the terminator, first observed here in 1890, are of a much more extreme character; and aside from the polar caps are possibly the most interesting and significant phenomena ever observed on *Mars*. The observations of 1890 are described in *Publications A. S. P.*, Vol. II, pages 248-9, from which we quote :

“The interesting phenomenon of bright spots projecting beyond the terminator of *Mars*, and presenting much the same appearance as the summits of lunar mountains and craters when first visible outside the terminator of the Moon, was well seen with the 36-inch refractor on the nights of July 5 and 6. The attention of the astronomers was directed to the aspect of *Mars* on July 5 at 10^h Pacific Standard time, by a visitor, who happened

* SCHIAPARELLI'S account of the bright spots observed by him is reprinted on later pages of this publication.

† Described in *Mémoires Couronnés, Académie Royale de Belgique*, Vol. LI.

to be looking in the telescope at that time, on one of the public nights of the Observatory. A sketch made by J. E. K. at this time shows a narrow, elliptical, white spot, from $1''.5$ to $2''.0$ long, projecting downward (northward) at a small angle with the line of the terminator. The seeing was 5, or the best which is known at the Observatory. At $10^h 30^m$ the spot was within the disc, but still visible as an oval white patch on a darker background.

"On July 6 the same appearance was more carefully observed by E. S. H., J. M. S. and J. E. K. A projecting spot was seen by E. S. H. at $8^h 3^m$ Pacific Standard time. At $8^h 45^m$ it curved upward and nearly met another smaller projecting spot some $2''$ farther toward the south. J. M. S. considered that there was an actual connection, although it was very faint.

"The lower spot, although it changed considerably in shape, remained visible for more than an hour, and was observed to be always situated on the end of a long bright stripe of the surface of the planet which lies north of *Deuteronilus*. The simplest interpretation of the phenomenon is therefore that this strip is (or was at the time of observation) elevated above the general surface. At about $10^h 25^m$ of July 6 the aspect was much the same as that of the spot seen on the preceding night and was no doubt produced by the same part of the planet."

Careful sketches of the appearances were made.

It should be stated that *Mars* was not observed at all on the nights preceding and following July 5 and 6, as the telescope was used in other work, and it cannot be said on how many nights these projections continued.

The projections were real. They were not caused by irradiation. They were not only elevated above the theoretical terminator, but the prominent ones curved round to the north into a position parallel with the terminator, and the northern end of the curved arm was separated from the illuminated disc by a dark line of appreciable breadth.

The latitude of the principal projection was very nearly $+40^\circ$. I have computed the longitudes of the terminator at $+40^\circ$ and found them to be as follows :

July 5 ^d	10 ^h	0 ^m	Longitude = $44^\circ.8$
	10	30	52 .1
6	8	3	6 .3
	8	45	18 .9
	10	25	40 .7

A comparison with SCHIAPARELLI's map will show that the projection observed July 5 covered the preceding end of the very bright region *Tempe*. The terminator at 10^h 25^m on July 6 was just at the beginning of *Tempe* and the bright projection, which was rapidly assuming its form as observed at 10^h of the preceding night, was covering the preceding end of *Tempe*.

Similar projections were observed on the terminator by Messrs. HOLDEN, SCHAEBERLE, HUSSEY and CAMPBELL at the opposition of 1892. Concerning these observations Professor HOLDEN says, in *Astronomy and Astro-Physics* for October, 1892 :

"A very interesting series of observations of bright projecting points on the terminator of the planet was begun by Mr. SCHAEBERLE and myself early in June, and was continued till the middle of July. * * * During the opposition of 1890, similar observations seemed to show that these projections were the prolongation of white streaks on the planet (clouds?), and the phenomena of 1892 have been examined to see if a similar conclusion would hold. The results have, so far, been indecisive."

Professor SCHAEBERLE has written as follows concerning his observations of the projections in June and July, 1892 :

"Where these dark streaks seem to intersect the limb of *Mars* the white areas projecting beyond the terminator of *Mars* (often noticed in June and July during the partial phase) were usually seen, indicating that the dark streaks were elevated above the general surface and rendered more bright by being projected against a dark background. That the bright areas projecting beyond the terminator actually lie in a dark streak needs further confirmation."—*Publications A. S. P.*, Vol. III, page 197.

M. PERROTIN, Director of the Nice Observatory, with their 30-inch equatorial, observed projections on the terminator of *Mars* on three occasions in 1892. His account of the observations was presented to the French Academy, and published in *Comptes Rendus*, Vol. CXV, pages 379-381. Concerning them he says :

"I would perhaps have still further delayed the sending of my letter if I had not received in the last few days from M. NEWCOMB an extract from a journal in which it is reported that the LICK astronomers have likewise observed the luminous projections on the edge of the disc."

The first projection was seen by M. PERROTIN on June 10,

from $15^h 12^m$ to $16^h 17^m$ Nice mean time, in the vicinity of -30° latitude. On July 2 a projection was visible at $14^h 10^m$ when observations for the night began, and disappeared at about $14^h 40^m$. Again, on July 3, the projection was visible at $14^h 11^m$ to $15^h 6^m$. Those of July 2 and 3 were estimated to be in latitude -50° , and to be produced in the same region of the planet. M. PERROTIN'S comments are as follows :

"Such are the facts. I shall not venture to interpret them. They were seen with such great distinctness that it is scarcely possible to consider them as the result of some illusion.

"Moreover, as we are here considering projections outside the disc of at least one or two tenths of a second of arc—that is to say, phenomena occurring at altitudes greater than 30 or 60 kilometres—the mind finds itself overwhelmed with such numbers, to which we are not accustomed on our globe, and it is doubtless only to phenomena purely luminous that we can look for the explanation of such altitudes."

Assuming the latitudes to be -30° , -50° and -50° on the three dates, I have computed the longitudes of the terminator at the points occupied by the projections observed by M. PERROTIN with the results :

1892 June	$10^d 15^h 12^m$ to $16^h 17^m$	$\beta = -30^\circ$	$\lambda = 212^\circ.4$ to $228^\circ.2$
July 2	$14 10$ to $14 40$	-50	335.4 to 342.8
	$3 14 11$ to $15 6$	-50	325.7 to 339.0

Professor HUSSEY, who took part in the LICK observations of *Mars* during July and August, 1892, observed one or more projections on every good night that he worked up to and including July 17, viz.: July 2, 5, 10, 11, 12, 13, 17. My observations were limited to parts of four nights a week between July 10 and August 17. I observed these projections on July 10, 11, 12, 13, 17; that is, on the first five nights that I used the telescope. I believe that no one here saw the projections *after* July 17, and that all the projections lay between latitudes -30° and -50° , with the exception of one or two minor prominences observed at about -25° . Those observed by Mr. HUSSEY and by me were all included between longitudes 310° and 95° . The most prominent ones were those observed on July 11 and 13. On July 11 two prominences were visible. The most striking one was visible when the observations began at $12^h 15^m$, and remained constantly in view for about two hours. Its shape changed a great deal during that time. At $13^h 25^m$ it was unusually prominent, and its

outer extremity was perceptibly bent upward toward the south polar cap. Measures of the position of the projection gave it an average latitude of -47° , but its south latitude continually increased. My notes on this point are, " $13^h 25^m$, distance from prominence to cap is less than at $12^h 55^m$;" and " $13^h 55^m$ prominence smaller and closer to cap than before." The longitude of the prominence varied from 340° to 7° . I did not reduce these observations till January, 1894, when a comparison of the results with SCHIAPARELLI'S maps showed pretty conclusively that the projections were either central on the bright region *Noachis* or on its southern border. The following end of *Noachis* approaches the polar cap, just as the projections so plainly did. A second and less prominent projection in latitude -33° was visible from $12^h 45^m$ to $13^h 55^m$ the same night.

On July 13, the observations of July 11 were substantially duplicated. The southern one of the two projections presented the hooked or bent appearance most strongly at $14^h 35^m$, just as it was seen two nights earlier at $13^h 25^m$; and therefore, allowing for the longer rotation period of *Mars*, the same point on the planet was under observation on the two nights. The position of the base of the prominence was latitude -46° , longitude 357° . The same part of the planet was on the terminator when observations were being made on July 10 and 12, and projections were seen at those times also, though the seeing was not so good.

It is not intended to include the details of the LICK observations of these projections in this paper. They will be published later in the general report of all the *Mars* observations made here in 1892 and 1894.

The only reference to these bright projections by the Arequipa observers appears to be the following statement by Mr. W. H. PICKERING in the December, 1892, *Astronomy and Astro-Physics*: "Clouds have on several occasions been observed to project beyond the terminator and also beyond the limb, thus confirming the observations made at the LICK Observatory. The height of some of these clouds has been measured, and it appears that some of them attained an altitude of at least twenty miles—a height considerably greater than that attained by terrestrial clouds. This is a result naturally to be expected from the small mass of the planet."

Such are the observations of the bright projections, and the

comments made by the observers. They do not seem to have received further attention from astronomers interested in Martian problems. Miss CLERKE adopts for her valuable *History of Astronomy* the observations and interpretations made by Mr. W. H. PICKERING; she attributes them likewise to the LICK observers and to M. PERROTIN, which is hardly correct. I believe the LICK astronomers and M. PERROTIN, so far as published accounts go, saw the projections only beyond the *terminator*, indeed on a very limited part of the terminator, and not at all beyond the *limb*.

I believe these projections can be explained on the hypothesis that they are due to mountain chains lying *across* the terminator of the planet, possibly covered with snow in some cases, and in others not necessarily so.

It is reasonable to suppose that mountains exist on *Mars*, and that they ought to be visible in large telescopes. The distance of the planet from the Earth on July 11, 1892, was approximately 39,000,000 miles. We were able to use powers of 350 to 520 diameters in our observations. The equivalent distances of the planet under those powers were 110,000 miles and 75,000 miles. Our Moon is more than two times 110,000 and more than three times 75,000 miles from us. Yet we are able *by naked eye* to see bright projections on the Moon's terminator caused by mountain chains or large craters. When the mountains surrounding *Sinus Iridum* are lying across the terminator, visitors have often asked me for an explanation of the bright projection at that point, seen by them by naked eye. One has only to examine photographs of the Moon at all ages of it to see how prominent the projecting mountains may become. These projections can never be seen on the Moon's bright limb by naked eye. Now, if we can observe prominences on the Moon's terminator at a distance of 240,000 miles *without a telescope*, we ought occasionally to detect similar phenomena on *Mars'* terminator when its equivalent distance in the telescope is less than half the Moon's distance.

To take an actually observed case, let us consider M. PERROTIN's observation of June 10, and assign to the prominence its maximum estimated apparent altitude, $0''.2$. The distance of the planet was at that time about 52,600,000 miles from the Earth. The apparent length of the projection would be 52,600,000 tangent $0''.2$, or 51.0 miles. Assuming the projection to be due to a mountain chain running out upon the non-illuminated surface

of *Mars*, high enough above the surface to catch the Sun's rays while the surrounding plains are not illuminated, the distance of the outer end of the illuminated mountain chain from the terminator would have to be equal to the apparent length of the projection divided by the sine of the angle at *Mars* between the Earth and Sun; that is, to 51.0 miles \div sine $35^\circ = 89.0$ miles. The approximate height of a mountain at a distance of 89.0 miles from the terminator, to be just illuminated, would have to be

$$\sqrt{(2100)^2 + (89.0)^2} - 2100 = 1.89 \text{ miles};$$

or a little less than 10,000 feet.

Other things being equal, if the projections are due to mountains, those seen in July would require an altitude somewhat greater than 1.89 miles.

It thus appears that mountains on *Mars*, to be seen under suitable conditions, need be only of moderate height, entirely comparable with those on the Earth and the Moon; and *vice versa*, that if mountains exist on *Mars* of the same order of altitude as those on the Earth and Moon, we ought to be able to see them whenever they are on the terminator and the other conditions are favorable.

If a mountain at the *terminator* becomes visible to us, we do not see it principally by virtue of its *altitude*, as one observer seems to have considered, but almost wholly by virtue of the *length* of the mountain chain under illumination. Due allowance must be made for the fact that the observer is viewing *Mars* from the Earth, and not from the Sun. If a mountain were on the *limb* at a given instant we could see it only by virtue of its *altitude*, and the *length of the chain* would not enter. No projections from the limb were observed here or at Nice, as was stated above.

The mountain chain hypothesis satisfactorily accounts for the more or less permanent character of the projections. They were seen night after night in the same places. At the 1892 opposition they were restricted to the belt between 30° and 50° of south latitude. Possibly they were under suitable illumination in that region, and not in other regions.

There can be no objection to the assumption that the mountains in that region were covered with snow. If the polar caps are composed of snow, we should expect the high mountain tops in all latitudes to be covered with snow at some time in the Martian year. Possibly those in south latitudes 30° to 50° were

covered with snow and were excessively bright in consequence in June and July, 1892. The July projections nearest the south polar cap were brighter than the more distant ones. It should be mentioned that several observers have drawn *Mars* with very bright and narrow spurs jutting out from the polar cap. It is possible or probable that these are mountain ranges from whose tops the snows melt later than they do from the surrounding plains. It is possible also that the Martian mountains are not elevated enough to be visible even on the terminator except when they are made excessively brighter than surrounding areas by snow on their summits. The fact that projections were not equally visible both before and after oppositions, points to some connection with the Martian seasons; as, for example, the melting of the snow on mountain tops as the summer seasons come on.

It has been suggested that the projections may be due to clouds. That theory has some points in its favor; but on the whole it seems unsatisfactory. We are not accustomed to attach as much permanency to terrestrial clouds as these projections have shown. They were observed night after night apparently in the same positions. Those of July 11 and 13, for instance, were visible for two hours, certainly, and probably longer, during which time 800 or 900 miles of the planet passed over the terminator. Those projections were caused by narrow and long objects. They corresponded in position to recognized permanent features of the surface. Bright spots on the surface were observed by SCHIAPARELLI and others to exist for months without sensible change. If SCHIAPARELLI's bright spots, and the bright projections above described were due to clouds, they could probably only be due to clouds resting on cold mountain tops, as they are often seen for days or weeks hanging over terrestrial mountains. But that carries us back substantially to the mountain theory.

It will not be possible to establish any theory until the projections have been accurately observed at several oppositions, or possibly through one or more of the 15-year cycles. The mountain theory is offered here as a working hypothesis.

At the next opposition the position of every projection should be measured as accurately as possible, and its latitude and longitude computed. When that longitude is on the central meridian, the position occupied by the projection can be set off by means of the micrometer, and it ought to be possible to say whether it falls upon a bright or a dark region. The importance

of this method of deciding whether land areas on *Mars* are light or dark is very evident. My accurate measures of July 11 and 13 seem to place the brightest projection upon SCHIAPARELLI'S broad bright region *Noachis*; but a much more extensive series of measures is required to establish the identity satisfactorily.

Great care must be taken in measuring the position of a projection. I would recommend the following method: MARTH'S valuable ephemeris of *Mars* gives the "position angle of the greatest defect of illumination." With the micrometer wires set to that position angle, place the fixed wire tangent to the upper limb and bisect the projection with the movable wire. Again, place the fixed wire tangent to the lower limb and bisect the projection with the movable wire. The diameter of the planet should also be measured, without changing the position angle of the wires. Irradiation caused by the bright polar cap is liable to increase some of the distances measured, especially with small telescopes.

Whatever may be the cause of these interesting prominences projecting out from the terminator, it is clear that the objects observed need not be higher than the mountains on the Earth and Moon.

MOUNT HAMILTON, February 1, 1894.